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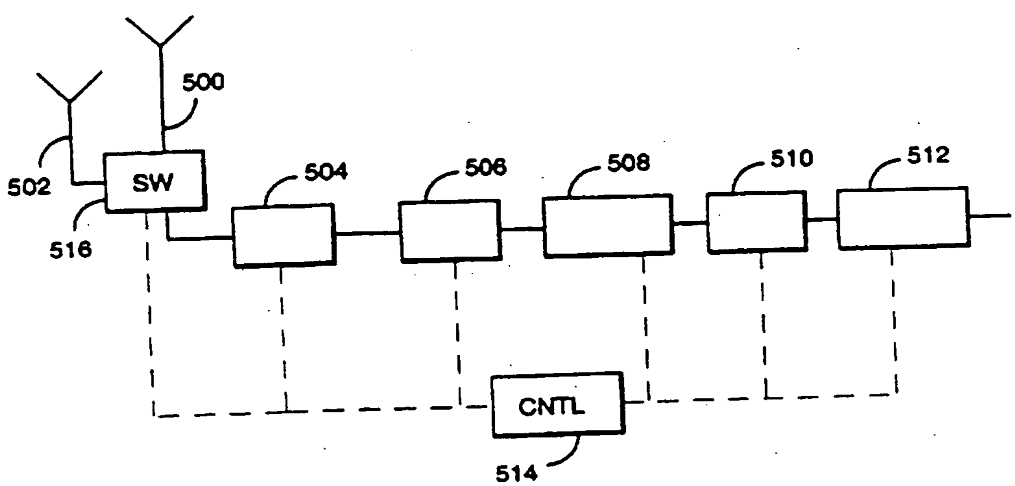
(54) Title: A METHOD FOR IMPROVING CONNECTION QUALITY IN A CELLULAR RADIO SYSTEM AND A RECEIVER UNIT



(57) Abstract

The invention relates to a method for improving connection quality in a cellular radio system, and a receiver in a cellular radio system which comprises at least one base station (BS) in each cell and subscriber units (MS) which communicate with the base stations employing time division multiple access, the receiver comprising means (504, 508, 514) for receiving and measuring a signal from a transmitter. To allow antenna diversity to be implemented in low-cost subscriber and base stations units, the receiver according to the invention comprises at least two antenna means (500, 502) for receiving signals from the transmitter, means (508) for measuring, at the beginning of each data burst, the quality of the signal received at the receiver with each antenna over a given time period, switching means (516) for connecting the desired antenna to the receiving and measuring means (508), means (514) for comparing the measurement results, and means (514) for instructing the switching means (516) to select the antenna giving the best quality for receiving the remainder of the data burst.

A method for improving connection quality in a cellular radio system and a receiver unit

Field of the invention

The present invention relates to a method for improving connection quality in a cellular radio system in which base stations and subscriber units communicate with each other employing time division multiple access, said method comprising the steps of receiving a signal at a receiver with at least two antenna branches, and measuring the quality of the signal received with each antenna.

Description of the prior art

In a typical radio telephone environment, the quality of a radio channel between a subscriber unit and a base station varies as a function of place and time. The field generated by a base station antenna does not attenuate homogeneously according to distance, but the field strength varies depending on the location even if the distance from the antenna remains the same. These variations are due to the fact that there is no line of sight between the transmitting and receiving antennas, but there are obstructions caused by the terrain or buildings on the propagation path. The environment thus causes fades and reflections to a transmitted signal, and the signal received by a subscriber unit is often a sum of signal components propagated along several different paths. Local variations in signal strength may be extremely great.

Local fades may cause calls to be interrupted, as the connection quality suddenly deteriorates.

A known method for mitigating the impairment resulting from multipath propagation in radio telephone systems is antenna diversity. In antenna diversity the receiver utilizes at least two antennas in the reception of the signal. The antennas are placed at a given distance from each other or receive with different polarizations, and thus the signal strength received by each antenna may vary independently. The receiver may select the antenna giving the best signal quality at each time instant.

There are several known methods for selecting or combining the signals received with different antennas. For most diversity combining methods, a separate receiver is needed for each antenna branch, which makes antenna diversity implementation costly and sizable. Thus antenna diversity has so far been mostly used in base stations. Linear combining schemes, such as Maximum Ratio, Equal Gain and Selection Combining, which have been used in base stations, and which require separate receivers for each antenna, are not feasible in low-cost subscriber and base station units.

A known diversity combining method, which in terms of hardware requires only one receiver equipment that switches between used antennas, is a nonlinear combining method called Switching Diversity. One example of switching diversity methods is described in patent application DE 4236089 "Verfahren und Anordnung zur Aktivierung von Antennen einer Funksende-/Empfangseinrichtung". However, the performance of Switching Diversity is poor compared to linear combining methods, and it often implies power correlation between receiver data bursts.

Brief description of the invention

Therefore, it is an object of the present invention to provide a diversity method which, in terms of hardware, can be implemented in low-cost subscriber and base station units of a radio telephone system.

It is another object of the present invention to provide a diversity combining method whose performance is nearly equal to that of linear combining methods.

Accordingly, these and other objects are achieved with the method described in the introduction, said method being characterized in that, at the beginning of each data burst, the quality of the signal received at the receiver on each antenna branch is measured over a given time period using the same receiver unit for each measurement, and that the antenna giving the best quality is selected by comparing the measurement results, and that the remainder of the data burst is received using the antenna which gives the best signal quality.

The invention further relates to a receiver in a cellular radio system which comprises at least one base station in each cell and subscriber units which communicate with the base stations employing time division multiple access, said receiver comprising means for receiving and measuring the signal from the transmitter. The receiver of the invention is characterized in that it comprises at least two antenna means for receiving the signal from the transmitter, means for measuring, at the beginning of each data burst, the quality of the signal received at the receiver with each antenna over a given time period, switching means for connecting the desired antenna to the receiving and measuring means, means for comparing the measurement

results, and means for instructing the switching means to select the antenna giving the best quality for receiving the remainder of the data burst.

The method according to the invention requires only one receiver equipment, and yet almost the same improvement is achieved in the signal quality as in the linear diversity combining methods, which are considerably more costly to implement. Thus, the method according to the invention allows antenna diversity to be implemented even in the downlink direction (the direction from the base station to the subscriber unit). The method can also be implemented in low-cost base station units.

Brief description of the drawings

In the following, the invention will be described in more detail with reference to the examples according to the accompanying drawings, in which

Figure 1 shows a cellular radio system in which the method of the invention can be applied,

Figure 2 illustrates the structure of a TDMA frame in the GSM system,

Figure 3 illustrates the structure of a GSM data burst,

Figure 4 is a block diagram of the structure of the receiver according to the invention.

Detailed description of the preferred embodiments

Figure 1 illustrates a cellular radio system in which the method according to the invention can be applied. In each cell the cellular radio system comprises at least one base station BS, which communicates with the subscriber units MS located within its

area. The method of the invention can be applied in any cellular radio system employing a time division multiple access (TDMA) method, such as the GSM and DECT. In the following, the invention will be described in connection with the GSM system; however, the invention is not restricted to this example.

In the GSM system, a TDMA frame comprises eight time slots. The structure of the frame is illustrated in Figure 2. The time slots of the frame are numbered from 0 to 7. Several carrier frequencies may be used in each cell. The structure of a normal GSM data burst is illustrated in Figure 3. The burst comprises a training sequence or midamble of 26 bits in the middle of the sequence and 58 encrypted bits of user data on each side of the midamble. The burst further comprises three tail bits at each end of the burst. Between the successive time slots there is an 8.25 guard period (not shown).

The method according to the invention will be described in the following with reference to Figure 3, assuming that the subscriber unit is equipped with two antennas, Branch 1 and Branch 2. It should be noted, that the invention is not limited to the use of two antennas, but there may also be more than two antennas. According to the invention, the quality of the signal using both antennas is measured at the beginning of each burst, and the antenna which gives better quality is used for the reception of the remainder of the burst. Part of the burst will be lost because of the measurements, but interleaving and efficient coding methods make the frame error rate nearly insensitive to corruption of a few bits at the beginning of the burst. Let us further assume in the following that Branch 2 refers to the antenna that was selected for reception in the last data burst received.

In the preferred embodiment of the invention, the receiver, at the beginning of each burst, estimates the signal quality during the next k bits for Branch 1. Then the receiver is switched to Branch 2. The switching time is denoted with m, which means the number of bit periods required for antenna switching and receiver settling. The receiver then estimates the signal quality during the next k bits for Branch 2. The antenna branch that gives the better quality will be selected for reception for the remainder of the burst. If Branch 1 is selected, the maximum number of corrupted bits will be $2*(k+m)$. If Branch 2 is selected, only $k+m$ bits will be corrupted.

A typical measure that can be used for signal quality is Received Signal Strength Indication (RSSI). Thus, if the measurement from Branch 1 is denoted by $RSSI_1$ and the measurement from Branch 1 is denoted by $RSSI_2$, the antenna selection procedure can be described as

if $RSSI_1 > RSSI_2 + L$ then select Branch 1
else select Branch 2,

where L denotes a given constant, which typically has the value 0.

When measurements are made, there will occur some loss of received bits. That is, the bits received before the last antenna switching will be lost. In the GSM system, the frame error rate, which denotes the quality of the received frame, will not drop even if some of the first bits in the frame are lost. This is because the GSM forward error correction and the interleaving methods and half rate encoding used in GSM transmission combined with soft information output from the data receiver tolerate some data loss. Also, the

improvement which the antenna diversity gives fully compensates for the loss of bits.

Typical values for parameters *k* and *m* are 5 bits and 3 bits, respectively, but other combinations are possible as well.

The structure of the receiver according to the invention will be described in the following. The receiver may be a subscriber unit or a base station receiver. The basic elements of the receiver are the same in either case. The receiver according to the invention is illustrated in Figure 4 by means of a block diagram. The receiver comprises at least two antennas 500, 502, which are connected to the radio frequency elements 504 via a radio frequency switch 516. The radio frequency elements 504 convert the received signal to intermediate frequency. From the radio frequency elements 504, the received signal is supplied to an analog-to-digital converter 506, where the signal is converted into digital form. The converted signal is further processed in a demodulator 508, which demodulates and detects the received symbols. From the demodulator, the signal is supplied to conventional channel decoder and speech decoder means 510 and 512, respectively.

The receiver according to the invention further comprises control means 514, which control the operation of the elements mentioned above. The control means are usually implemented by means of a processor, but it will be clear to one skilled in the art that they can also be implemented by using discrete electronic components.

The receiver according to the invention further comprises means 508 for measuring, at the beginning of each data burst, the quality of the signal received at the receiver with each antenna over a given time period. The receiver comprises switching means 516 for connect-

ing the desired antenna 500, 502 to the receiving and measuring means 508 and means 514 for controlling the switching means 516. The control means 514 also compare the measurement results and select the antenna giving the best quality for receiving the remainder of the data burst.

The receiver according to the invention further comprises several other components such as filters and converters, as will be clear to one skilled in the art, but for reasons of clarity these components are not shown in the block diagram.

Although the invention has been described above with reference to the examples illustrated by the accompanying drawings, it will be obvious that it may be modified in many ways. Such modifications are not to be regarded as a departure from the spirit and scope of the invention; all such modifications as would be obvious to one skilled in the art are intended to be included within the scope of the appended claims.

Claims

1. A method for improving connection quality in a cellular radio system in which base stations (BS) and subscriber units (MS) communicate with each other employing time division multiple access, said method comprising the steps of

receiving a signal at a receiver with at least two antenna branches (500, 502), and

measuring the quality of the signal received with each antenna,

c h a r a c t e r i z e d in that at the beginning of each data burst, the quality of the signal received at the receiver on each antenna branch is measured over a given time period using the same receiver unit for each measurement,

the antenna giving the best quality is selected by comparing the measurement results, and

the remainder of the data burst is received using the antenna which gives the best signal quality.

2. A method according to claim 1, c h a r a c - t e r i z e d in that the quality of the received signal is measured using the received signal strength.

3. A method according to claim 1, c h a r a c - t e r i z e d in that the measurement time period is considerably shorter than the length of the data burst.

4. A receiver in a cellular radio system which comprises at least one base station (BS) in each cell and subscriber units (MS) which communicate with the base stations employing time division multiple access, said receiver comprising

means (504, 508, 514) for receiving and measuring a signal from a transmitter,

c h a r a c t e r i z e d in that it comprises

at least two antenna means (500, 502) for receiving the signal from the transmitter,

means (508) for measuring, at the beginning of each data burst, the quality of the signal received at the receiver with each antenna over a given time period,

switching means (516) for connecting the desired antenna to the receiving and measuring means (508),

means (514) for comparing the measurement results and

means (514) for instructing the switching means (516) to select the antenna giving the best quality for receiving the remainder of the data burst.

5. A receiver according to claim 4, c h a r a c t e r i z e d in that it further comprises means (504) for converting the received signal into intermediate frequency, means (506) for converting the signal into digital form, means (508) for demodulating the converted signal, and means (514) for controlling the operation of the receiver.

6. A receiver according to claim 4, c h a r a c t e r i z e d in that it is a subscriber unit (MS).

7. A receiver according to claim 4, c h a r a c t e r i z e d in that it is a base station receiver (BS).

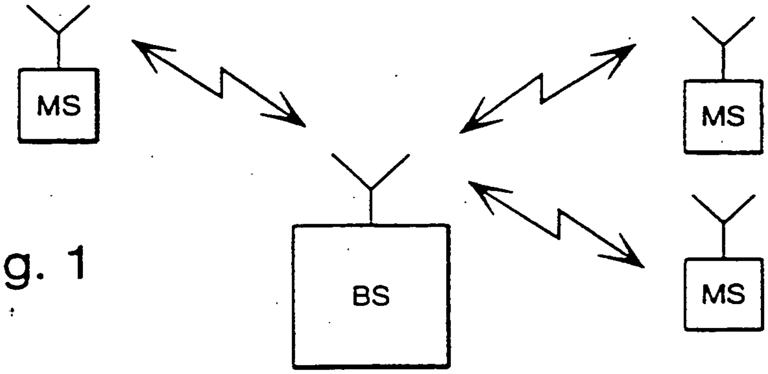


Fig. 1

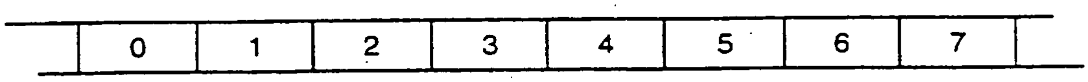


Fig. 2

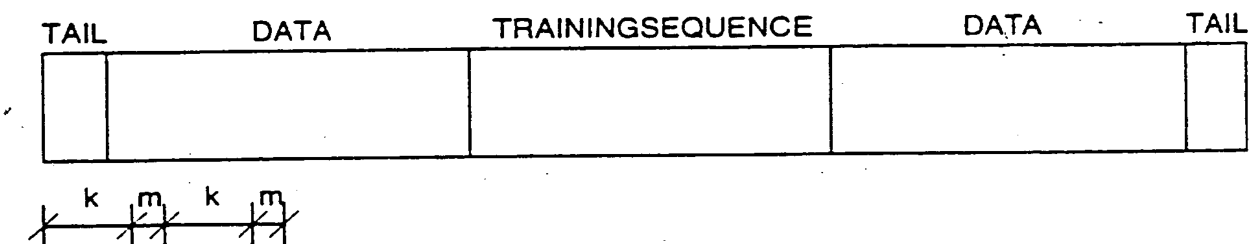


Fig. 3

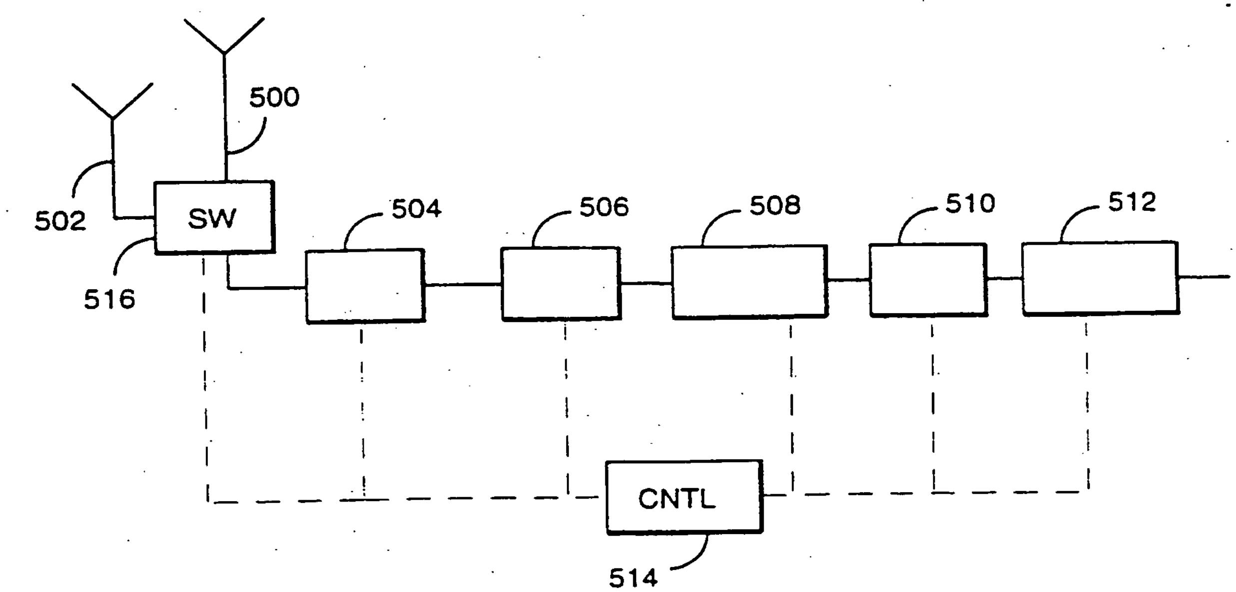


Fig. 4

INTERNATIONAL SEARCH REPORT

International application No.
PC[illegible] 95/00470

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: H04B 7/08
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 9415411 A1 (MOTOROLA, INC.), 7 July 1994 (07.07.94), page 2, line 15 - page 3, line 30 --	1-7
X	WO 9408404 A1 (NORTHERN TELECOM LIMITED), 14 April 1994 (14.04.94), page 3, line 4 - line 16 --	1-7
X	Patent Abstracts of Japan, Vol 12,No 423, E-680, abstract of JP, A, 63-158922 (NEC CORP), 1 July 1988 (01.07.88) --	1-7
X	EP 0454585 A1 (NIPPON TELEGRAPH AND TELEPHONE PUBLIC CORPORATION), 30 October 1991 (30.10.91), page 3, line 40 - page 4, line 35 --	1-7

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

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"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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Date of the actual completion of the international search	Date of mailing of the international search report
20 February 1996	21 -02- 1996
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INTERNATIONAL SEARCH REPORT

International application No.
T/FI 95/00470

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
E,X	SE 9402493-2 A (TELEFONAKTIEBOLAGET L M ERICSSON), 16 January 1996 (16.01.96) -- --------	1-7

INTERNATIONAL SEARCH REPORT
Information on patent family members

05/02/96

International application No.
PCT/[illegible]95/00470

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WO-A1- 9415411	07/07/94	NONE	
WO-A1- 9408404	14/04/94	NONE	
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		DE-D,T- 69103196	23/02/95
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		JP-A- 4011416	16/01/92
SE-A- 9402493-2	16/01/96	NONE	